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DEVELOPMENT AND MODIFICATION OF A RESPONSE CLASS VIA POSITIVE AND NEGATIVE REINFORCEMENT: A TRANSLATIONAL APPROACH

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When responses function to produce the same reinforcer, a response class exists. Researchers have examined response classes in applied settings; however, the challenges associated with conducting applied research on response class development have recently necessitated the development of an analogue response class model. To date, little research has examined response classes that are strengthened by negative reinforcement. The current investigation was designed to develop a laboratory model of a response class through positive reinforcement (i.e., points exchangeable for money) and through negative reinforcement (i.e., the avoidance of scheduled point losses) with 11 college students as participants and clicks as the operant. Results of both the positive and negative reinforcement evaluations showed that participants usually selected the least effortful response that produced points or the avoidance of point losses, respectively. The applied implications of the findings are discussed, along with the relevance of the present model to the study of punishment and resurgence.

Key words: avoidance, clicks, human operant behavior, negative reinforcement, positive reinforcement, response class, translational research

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When a group of responses result in the same consequence, a functional response class exists (Catania, 2007). One response may substitute for another and result in an ordered, temporal sequence of responding (Harding et al., 2001), and the sequence of responding (i.e., a response class hierarchy) may be influenced by reinforcement rate and response effort, among other variables (Baer, 1982). When reinforcement is held constant across several available responses, an organism will likely emit the response that requires the least caloric expenditure (physical effort). Through a concurrent-schedules arrangement, one can examine the distribution of responses in a class that vary in terms of physical effort, because each response is associated with an independent reinforcement schedule (Fisher & Mazur, 1997).

In the applied behavior analysis literature, response-class hierarchies have accounted for escalating sequences of problem behavior, as illustrated by several different research groups (Albin, O'Brien, & Horner, 1995; Borrero & Borrero, 2008; Lalli, Mace, Wohn, & Livezey, 1995; Magee & Ellis, 2000; Richman, Wacker, Asmus, Casey, & Andelman, 1999). Although the present study is concerned with functional response classes and not necessarily response classes whose members are hierarchically ordered, applied research on the latter has considerably informed research on the former. These studies have illustrated the existence and

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modification of response classes made up of various forms of problem behavior reinforced by either positive reinforcement (e.g., attention) or negative reinforcement (i.e., escape from instructional demands). In these applied examples of response classes, specific topographies of problem behavior (e.g., aggression) produced reinforcers, while other responses in the class (e.g., self-injury) did not; that is, the other responses were exposed to extinction. However, questions remain about how a response class or a response class hierarchy comes to be. For example, Lalli et al. (1995) suggested that a response class consisting of screams, aggression, and self-injurious behavior (SIB) exhibited by a 15-year-old girl might have developed because of differential response effort, rate of reinforcement, and rate of punishment across class members. However, because the reinforcement history associated with the development of the response class is unknown (Pipkin & Vollmer, 2009), determinations of how a class is initially formed also remain unknown. As Shabani, Carr, and Petursdottir (2009) noted recently, applied research on response classes can be challenging because responses in a class of severe problem behavior must be shown to serve the same function and then be sequentially exposed to extinction, which may place the individual in undue harm. To circumvent the potential challenges associated with identifying response classes that consist of various forms of problem behavior and the potential harm that may come from exposing severe problem behavior to extinction, Shabani et al. took the study of response classes back to the laboratory.

Shabani et al. (2009) assessed the development of a response class with one boy with a developmental disability and three girls with no known disabilities. Participants were taught an arbitrary response (i.e., a microswitch press) and received a small bite of candy or a penny that was exchangeable for preferred items postsession contingent on microswitch presses according to a fixed-ratio (FR) 1 schedule. Each switch required a different amount of effort, and effort was quantified along two dimensions: (a) the proximity of the switch to the seated participant and (b) the pressure required to activate the switch. The switch closest to the participant that required the least physical effort to activate was termed the low-effort switch (LE). The switch that was slightly farther away that required more pressure to activate was termed the medium-effort switch (ME), and the switch that was the farthest from the participant that required the most pressure to activate was termed the high-effort switch (HE). Participants experienced a series of conditions in which responses to only one, two, or all three available switches produced reinforcers. Presses on the switch or switches that were exposed to extinction resulted in no programmed consequences, and reinforcer magnitude was held constant across all three responses. Responses on the switches that were exposed to extinction occurred at zero to near-zero levels. Results showed that participants responded most on the switch that required the least physical effort and that produced reinforcers (for a similar finding, see Alessandri, Darcheville, Delevoye-Turrell, & Zentall, 2008).

Shabani et al. (2009) demonstrated that training a presumably novel response (e.g., switch pressing) could be used to study the development and modification of response classes and response class hierarchies in a translational research context. Although the procedures used by Shabani et al. might be conceptualized as a basic research study, current conceptions of translational research place it squarely along the translational research continuum. Woolf (2008) suggested that translational research can be thought of as comprising distinct areas of investigation, one in which research is conducted in laboratory settings to study problems of applied significance and another in which results from research studies are transferred into practice. The procedures and results of the study by Shabani et al. are important because they provide a testable framework to assess how response classes can be developed and modified in the laboratory, which is consistent with the first area of translational research described by Woolf. Doing so should permit a better understanding of response class development and modification involving multiple forms of severe problem behavior. Thus, one purpose of the current study was to conduct a systematic replication of the experiment of Shabani et al. by examining a response class developed via manipulations of physical effort.

Although Shabani et al. (2009) focused on the development and modification of response classes via positive reinforcement, the applied literature has shown that such classes can also develop via negative reinforcement (e.g., Lalli et al., 1995). Negative reinforcement operates when the removal, prevention, or attenuation of some stimulus results in an increase in the future probability of a response (Pierce & Cheney, 2004). In general, negative reinforcement procedures represent an umbrella category that subsumes escape (when the removal or attenuation of some stimulus strengthens behavior) and avoidance (when the postponement or prevention of some stimulus strengthens behavior). The applied behavior-analytic literature is replete with examples of problem behavior that is reinforced by escape (e.g., Iwata, Dorsey, Slifer, Bauman, & Richman, 1982/1994) but fewer illustrations of behavior that is reinforced by avoidance (e.g., McCord, Thomson, & Iwata, 2001).

Further study of negative reinforcement, particularly avoidance, may be informative in the context of translational research. In most applied contexts, however, avoidance involves the emission of behavior that prevents the presentation of some stimulus. This might be the case when occurrences of SIB prevent or postpone the presentation of a forthcoming aversive stimulus (e.g., an instructional demand). However, the study of avoidance may also entail the emission of behavior that prevents the removal of an appetitive stimulus. This might be the case when occurrences of academic engagement prevent the removal of points exchangeable for privileges in a token economy. This latter formulation of avoidance appears to be the subject of considerably less behavior-analytic research but is of equally important applied and conceptual relevance to behavior analysts (Iwata, 1987). Therefore, the second purpose of the current study was to extend the work of Shabani et al. (2009) under avoidance contingencies, again in a translational research context.

Research from the basic laboratory suggests some procedures that may permit study of avoidance and response classes (e.g., Cherek, Spiga, Steinberg, & Kelly, 1990; Weiner, 1969). Galizio (1979) exposed college students' behavior to a series of conditions in which a response was required (i.e., moving a lever) within an allotted time (a limited hold) to avoid point loss. In other words, if the response occurred but did not occur quickly enough, points were lost. Results showed that the participants efficiently avoided point losses. A similar procedure may be used to study response classes developed via negative reinforcement by including multiple responses that function to avoid the removal of a reinforcer. By varying response effort along some dimension (e.g., schedule requirement), an individual may emit a certain response at relatively higher rates, when that response results in avoidance or termination of the removal of some appetitive stimulus.

To reiterate, the current study was designed to investigate the development and modification of a response class rather than a response class hierarchy. Because it is difficult in applied settings to study a response class developed in terms of physical effort, this laboratory procedure provided a preliminary framework to assess the development and modification of such response classes using positive and negative reinforcement. In doing so, we may be better prepared to make informed decisions concerning treatments for members of a response class that involves socially significant behavior. Thus, the overarching objective of this work was to provide a model by which aspects of practical and applied significance (e.g., analysis of the utility of extinction as a treatment option) can be studied in the human operant laboratory.

GENERAL METHOD

Participants

Participants were undergraduate students enrolled at a public university in Maryland with a mean age of 19 years (range, 18 to 21). Eleven participants (five men and six women) completed both Experiments 1 and 2 and were recruited from undergraduate psychology courses. The institutional review board approved both experiments, and the experimenter obtained informed consent from participants prior to the study. The experimenter informed participants that they would be paid for their participation (equivalent to the point value earned in sessions). Some participants could also earn course extra credit after completion of the second session (contingent on instructor approval).

Apparatus and Setting

The experiment was conducted on a 33-cm laptop computer. The screen depicted three squares (red, yellow, and blue; 1.4 cm by 1.4 cm each). Participants made clicks on the screen by using the trackpad, which was a rectangular space (7.6 cm by 10.2 cm) on the laptop. The cursor moved on the screen when a participant dragged a finger across the trackpad. Squares were separated from each other by at least 5 cm. The squares were aligned in one row across the middle of the screen at the start of the session. A session consisted of 27 3-min blocks. At the start of each block, the participant was required to click on the start button. Then, the squares began to move in a random pattern across the computer screen. The squares continued to move across the screen until the end of each 3-min block. When a block was completed, the participant was again required to click the start button to initiate the next block until all 27 blocks were completed. When the participant met a ratio requirement for a square that was not exposed to extinction, the computer emitted a brief tone. Although the experimenter did not tell the participants, the tone signaled that the response requirement had been met, and was correlated with the presentation of a point on the counter that was visible to participants. There were no differential consequences for clicking boxes that were placed on extinction. An onscreen counter centered at the top of the screen displayed the amount of money earned. The amount shown was the cumulative amount of money earned (i.e., the counter was not reset at the start of each block).

Data were recorded via the application, which was developed with the Microsoft Visual Basic software program. The application, developed specifically for this study, allowed for real-time recording of the data via clicks on the squares. The application also permitted the analysis of response frequency.

The experiment was conducted in one of four laboratory spaces. Participants were required to leave all watches, cellular phones, and other belongings with the experimenter. The experimenter was not present in the room but could, and frequently did, observe performance from behind a one-way observation window that adjoined the experimental space.

Pilot Testing

Four pilot participants completed Experiment 1, and two of the four completed Experiment 2. The first author also completed Experiments 1 and 2. Pilot testing was conducted for three reasons: (a) to ensure that technological glitches associated with the program were identified and remediated, (b) to identify schedule values that would evoke responding and restrict participant earnings per session to a reasonable amount, and (c) to ensure that participants could physically emit 45 clicks within a 10-s period (which was most pertinent to Experiment 2). Data from the pilot testing indicated that schedule values of FR 5, FR 15, and FR 25 were viable options to develop a response class and were practical for financial purposes. In addition, pilot testing suggested that the emission of 45 responses was possible during a 10-s interval.

EXPERIMENT 1

Development of a Response Class via Physical Effort Manipulations and Positive Reinforcement

Method

Dependent variables and data collection. The software program recorded each click as a single occurrence and recorded responses during 1-s intervals of every session (again, a session consisted of 27 3-min blocks). Frequency of clicks was converted to a rate (responses per minute), which was the primary dependent variable. Clicks on each square resulted in points that were exchangeable for money after completion of Experiment 2 (described below). In Experiment 1, the effort required to earn points was manipulated. Specifically, the number of clicks on each square required to earn points varied. The square that required the least amount of effort on an FR 5 schedule (i.e., five clicks) was termed the LE square. The square that required completion of an FR 15 schedule was termed the ME square, and the last square required completion of an FR 25 schedule and was termed the HE square. The LE square was red, the ME square was yellow, and the HE square was blue. These colors were consistently associated with the corresponding schedule requirements for both studies. Participants were not given the schedule values, and nothing on screen informed them of the number of responses that had been emitted on the various squares. Again, a brief tone was correlated with point presentation. A changeover penalty reset the number of clicks made on a given square if the participant switched to another square (i.e., the participant needed to make consecutive clicks on one square to meet the ratio requirement and earn points). For example, if the participant emitted four responses on the LE square, then switched to the ME square and clicked once, and then switched back to the LE square and emitted one response, only one response would have been credited toward meeting the response requirement on the LE square after switching from the ME square. The purpose of including the consecutive response requirement was to decrease the likelihood of reinforcement for superstitious response sequences.

Design and procedure. Experiment 1 represented a systematic replication of procedures described by Shabani et al. (2009). The design incorporated features of a withdrawal design that were assessed in the context of a concurrent-schedules design. With the combined design, experimental control was demonstrated across conditions by way of the withdrawal component and within a condition by way of response differentiation between the concurrent schedules. The conditions in Experiment 1 were randomized across participants. Specifically, the class development and two of the class-modification conditions were randomly determined for each participant. The experimental sequence for each participant is presented in Table 1. For both Experiments 1 and 2, conditions were terminated based on the passage of time, not stability of performance, which is not uncommon in human operant research (e.g., Pipkin, Vollmer, & Sloman, 2010). Three 3-min blocks were conducted with each participant, per condition. Prior to Experiment 1, the experimenter told participants the following: "The object is for you to earn as much money as you can by clicking the squares on the screen. Ready, go." The experimenter did not give any additional information concerning the procedures. Ques-

Table 1
Sequence of Conditions and Cumulative Points Earned (Experiment 1) and Cumulative Point Losses Avoided (Experiment 2)

Participant	Sequence of conditions: Class development			Class demonstration	Class modification				Points earned or avoided losing: S^{R+} no max set	S^{R-} max: $7.56
Manuel	LE	ME	HE	LMH	MH	LH	MH	LM	$26.72	$3.29
Rinita	HE	LE	ME	LMH	MH	LH	MH	LM	$16.96	$4.00
Sebastian	ME	HE	LE	LMH	MH	LM	MH	LH	$29.91	$4.17
Atticus	HE	ME	LE	LMH	MH	LM	MH	LH	$20.92	$4.36
Francis	LE	HE	ME	LMH	MH	LM	MH	LH	$16.10	$4.26
Mindy	HE	LE	ME	LMH	MH	LM	MH	LH	$8.03	$3.73
Nathaniel	ME	LE	HE	LMH	MH	LH	MH	LM	$22.05	$5.51
Pandia	ME	HE	LE	LMH	MH	LM	MH	LH	$24.76	$4.16
Rhea	LE	ME	HE	LMH	MH	LM	MH	LH	$19.61	$6.15
Bia	LE	HE	ME	LMH	MH	LH	MH	LM	$25.27	$4.25
Pepromene	HE	ME	LE	LMH	MH	LH	MH	LM	$13.87	$1.21

Note. LE condition: FR 5 LE, EXT ME and HE; ME condition: EXT LE, FR 15 ME, EXT HE; HE condition: EXT LE and ME, FR 25 HE; LMH condition: FR 5 LE, FR 15 ME, FR 25 HE; MH condition: EXT LE, FR 15 ME, FR 25 HE; LH condition: FR 5 LE, EXT ME, FR 25 HE; LM condition: FR 5 LE, FR 15 ME, EXT HE. Baseline preceded all conditions.

tions regarding the procedures were unanswered or the experimenter responded by repeating the previously stated instruction, as described by Shabani et al.

For all participants, the no-reinforcement baseline condition was always conducted first. During baseline, all three squares were present, but no points were provided for clicking on any of the squares. This condition was conducted to ensure that responding occurred at low levels in the absence of points. Following baseline, each participant was exposed to three conditions (determined randomly across participants) in which meeting a ratio requirement for only one of the squares resulted in points. These initial procedures, termed the class-development conditions, were conducted to ensure that behavior was sensitive to the changing effort required to meet the response requirement. The three conditions of the class-development portion of the study are described next. During the LE reinforcement condition, all three squares were present, but only clicks on the LE square resulted in points; the other two alternatives were exposed to extinction. During the ME reinforcement condition, all three squares were present, but only clicks on the ME square resulted in points. During the HE reinforcement condition, all three squares were present, but only clicks on the HE square resulted in points. Following the third condition of the class-development portion, participants experienced the class-demonstration condition. This was the fifth condition for all participants. In the class-demonstration condition (LMH), all three squares were present, and points were provided for each square in accordance with the ratio requirements of each square. This condition was conducted to determine how participants would respond when all three options produced reinforcers. Following the class-demonstration condition, participants experienced three class-modification conditions. In these conditions, only two of three options produced points; these conditions are described next. In the MH condition, all three squares were present, but only clicks on the ME and HE squares resulted in points. The MH condition was replicated once for all participants because pilot data indicated that a reversal to this

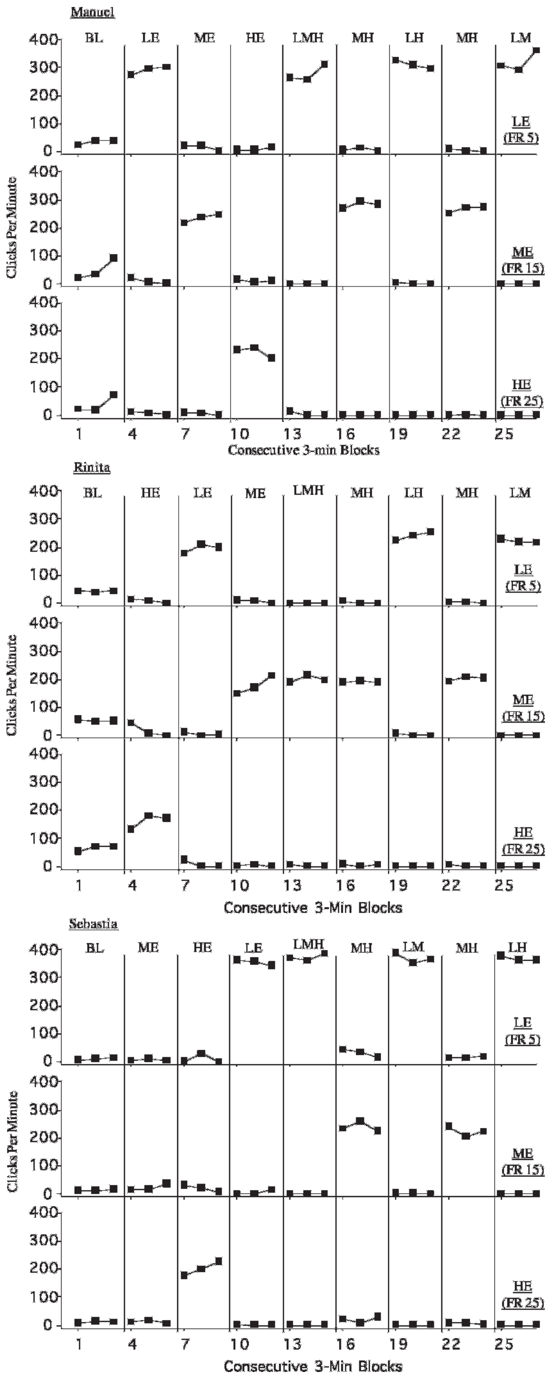

Figure 1. Results of Experiment 1 for Manuel, Rinita, and Sebastian depicted as responses per minute across the LE (top), ME (middle), and HE (bottom) options for each participant. LE condition: FR 5 LE, EXT ME and HE; ME condition: EXT LE, FR 15 ME, EXT HE; HE condition: EXT LE and ME, FR 25 HE; LMH condition: ← FR 5 LE, FR 15 ME, FR 25 HE; MH condition: EXT LE, FR 15 ME, FR 25 HE; LH condition: FR 5 LE, EXT ME, FR 25 HE; LM condition: FR 5 LE, FR 15 ME, EXT HE.

condition was necessary to shift responding from the LE square. In the LH condition, all three squares were present, but only clicks on the LE and HE squares resulted in points. Finally, in the LM condition all three squares were present, but only clicks on the LE and ME squares resulted in points.

Results and Discussion

Figures 1 through 4 depict results for all participants in Experiment 1. The data depicted in these and all figures represent the total frequency per unit time, not just responses that counted toward meeting the response requirement. For instance, a participant may have responded to the LE option 100 times in a given 3-min block of the LE condition, but this does not necessarily mean that any points were earned due to the changeover penalty. Overall effects were similar across participants; thus, results are summarized globally. Results are summarized in terms of mean responding observed in each condition, and specific condition means are available from the second author. The sequence differed across participants (Table 1 includes the specific sequence for each participant). In the following section, performances are summarized by experimental condition; therefore, the first condition experienced after baseline was not necessarily the LE condition, which will be summarized first. For example, the LE condition was the third condition for Mindy but the fourth condition for Atticus.

Compared to most of the reinforcement phases that followed, participants emitted low response rates during baseline. During the LE condition (FR 5 LE; EXT ME; EXT HE), responding was highest on the LE square and low on the ME and HE squares for 10 of 11

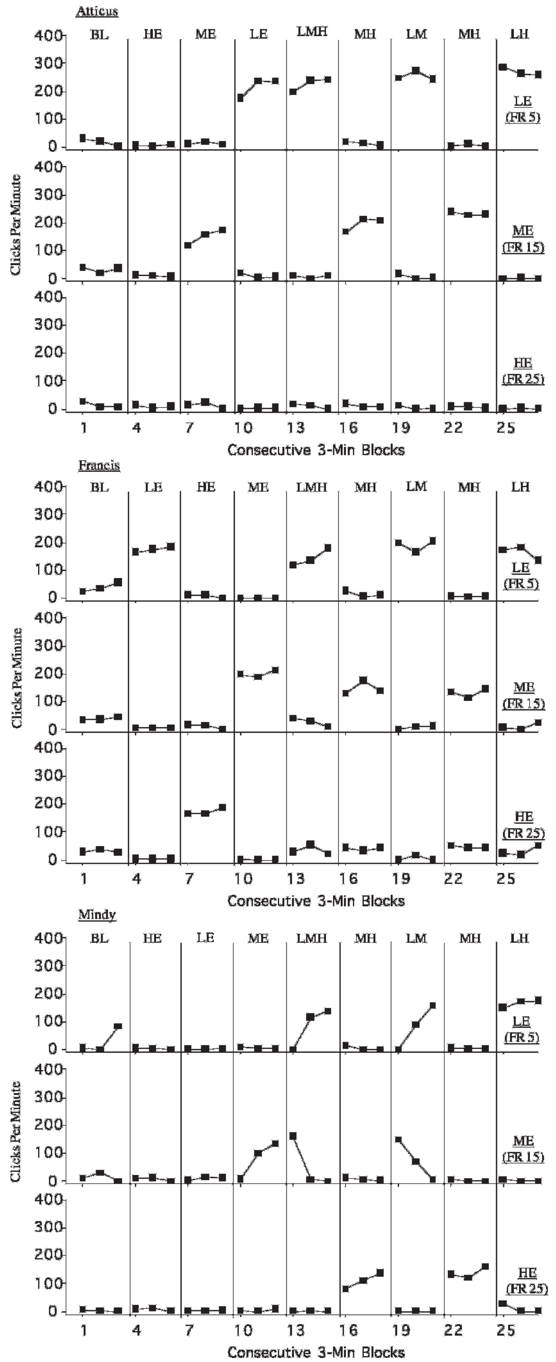

Figure 2. Results of Experiment 1 for Atticus, Francis, and Mindy depicted as responses per minute across the LE (top), ME (middle), and HE (bottom) options for each participant. LE condition: FR 5 LE, EXT ME and HE; ME condition: EXT LE, FR 15 ME, EXT HE; HE condition: EXT LE and ME, FR 25 HE; LMH condition: FR 5 LE, FR 15 ME, FR 25 HE; MH condition: EXT LE, FR 15 ME, FR 25 HE; LH condition: FR 5 LE, EXT ME, FR 25 HE; LM condition: FR 5 LE, FR 15 ME, EXT HE.

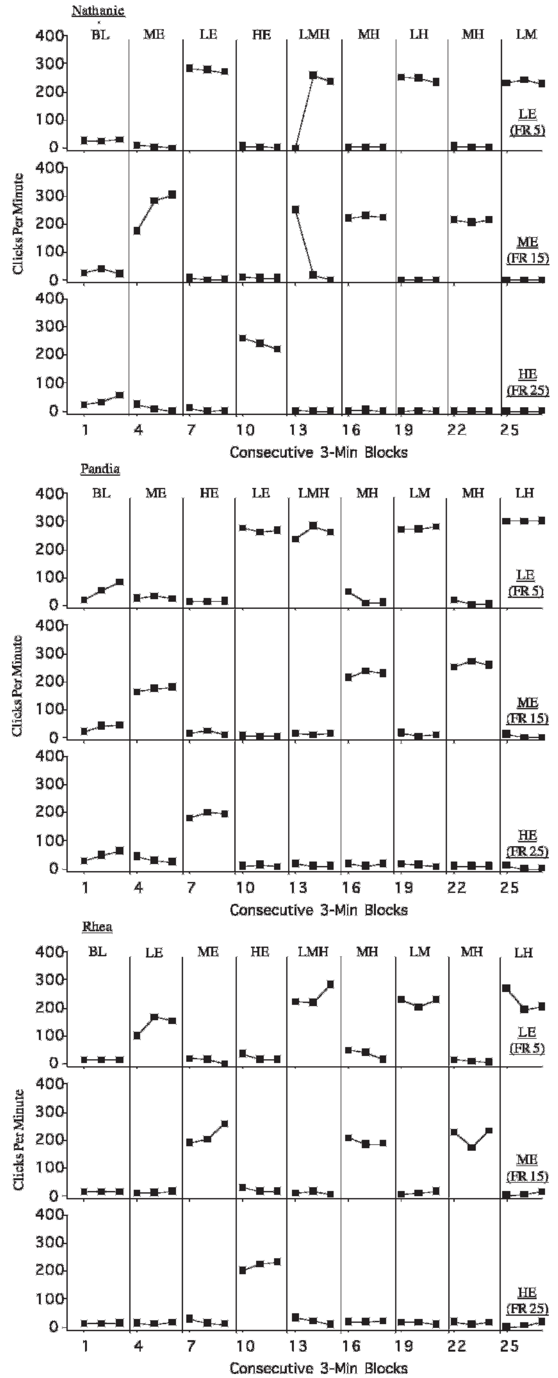

Figure 3. Results of Experiment 1 for Nathaniel, Pandia, and Rhea depicted as responses per minute across the LE (top), ME (middle), and HE (bottom) options for each participant. Condition descriptions are the same as those described for Figure 2.

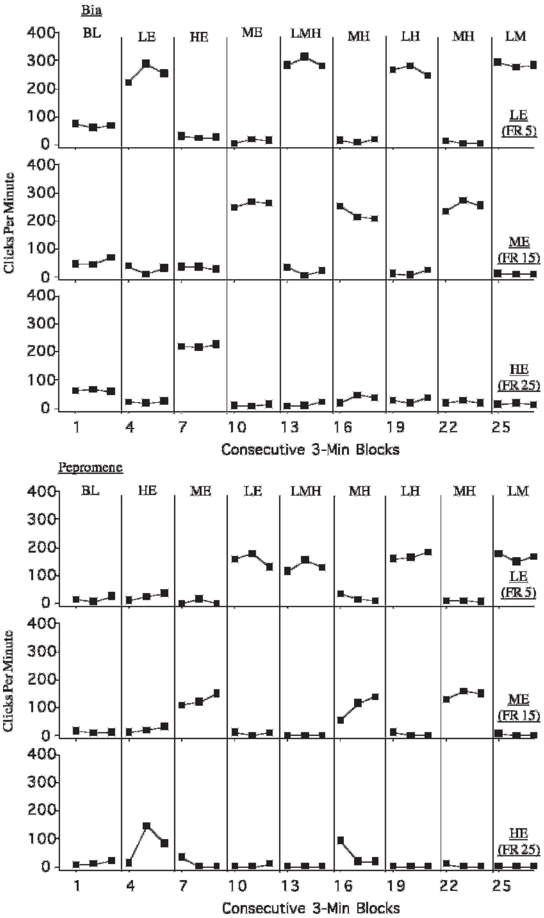

Figure 4. Results of Experiment 1 for Bia and Pepromene depicted as responses per minute across the LE (top), ME (middle), and HE (bottom) options for each participant. LE condition: FR 5 LE, EXT ME and HE; ME condition: EXT LE, FR 15 ME, EXT HE; HE condition: EXT LE and ME, FR 25 HE; LMH condition: FR 5 LE, FR 15 ME, FR 25 HE; MH condition: EXT LE, FR 15 ME, FR 25 HE; LH condition: FR 5 LE, EXT ME, FR 25 HE; LM condition: FR 5 LE, FR 15 ME, EXT HE.

participants. The exception was Mindy. During the ME condition (EXT LE; FR 15 ME; EXT HE), responding was highest on the ME square and low on the LE and HE squares for 11 of 11 participants. However, for Sebastian, the increase in responding was not observed until the last 3-min block of that condition. During the HE condition (EXT LE; EXT ME; FR 25 HE), responding was highest on the HE square and low on the LE and ME squares for 9 of 11 participants. The exceptions, Atticus and Mindy, engaged in low response rates during this condition. For these two participants, the HE condition was the first reinforcement condition, thus, these participants might not have contacted the FR 25 contingency without a prior history of the LE or ME conditions. However, Rinita and Pepromene also experienced the HE condition immediately following baseline, and response differentiation was observed. A possible explanation for the inefficient responding by Sebastian, Atticus, and Mindy during the class-development conditions could also be due to the changeover penalty. That is, the participants may have made more frequent switches between the three options than other participants, thereby resulting in more frequent encounters with the changeover penalty and less contact with the reinforcement contingencies.

During the class-demonstration condition (FR 5 LE; FR 15 ME; FR 25 HE), responding was highest on the LE square for 10 of 11 participants, and rates on the ME and HE squares were considerably lower. The exception, Rinita, emitted the highest rates on the ME square, which likely represented a carryover effect from the previous ME condition. That is, in the prior condition the ME alternative was the most lucrative, and exposure to the class-demonstration condition did not alter behavior because the ME option continued to produce reinforcers.

During the class-modification conditions that followed, responding was highest on the schedule that required the least effort that was not exposed to extinction. During both MH exposures (EXT LE; FR 15 ME; FR 25 HE), responding was highest on the ME square and low on the LE and HE squares for 10 of 11 participants. The exception was Mindy. During the LH condition (FR 5 LE; EXT ME; FR 25 HE), responding was highest on the LE square, and responding was low on the ME and HE squares for 11 of 11 participants. Similarly, during the LM condition (FR 5 LE; FR 15 ME; EXT HE), responding was highest on the LE square and was low on the ME and HE squares for 11 of 11 participants. Mindy initially responded at high rates on the ME square, but responses to the LE square increased and responses to the ME square decreased following the first 3-min block of this condition. A response class was successfully developed via positive reinforcement and subsequently modified for 10 of 11 participants. Mindy was the exception.

In accord with the prevailing contingencies, participants frequently selected the response alternative associated with the fewest number of required responses. Results of Experiment 1 represent a systematic replication of those reported by Shabani et al. (2009) with college students as participants, clicks as the operant, and points exchangeable for money as the reinforcer. Notable is the finding that the establishment and modification of the response class were accomplished in slightly more than 80 min, and thus suggests that the study of behavioral processes in the human operant laboratory is a viable and relatively efficient venue for the study of phenomena that are relevant in applied contexts that involve socially significant populations (e.g., individuals with intellectual disabilities). Also of note is the finding that behavior during the first 3 min of each condition was usually similar to that observed in the subsequent 6 min. This suggests that the study of response classes might be feasible in experimental sessions that last only 27 min (or perhaps even less), making the procedure more amenable to young children and individuals with disabilities. Because we cannot systematically investigate how response classes involving forms of severe problem behavior originate, the study of potentially analogous procedures in the human operant laboratory provides a convenient and well-controlled environment in which to model environmental contingencies that may be operating in the natural environment (Hake, 1982). For example, the three alternatives in Experiment 1, each varying in degree of effort, could be conceptualized as three different forms of problem behavior (e.g., screams, aggression, and SIB). Unlike prior applied studies in which participants begin an experiment with various forms of problem behavior firmly established, the response forms in the current study were developed in the laboratory and then subsequently exposed to contingencies that directed the occurrence of specific responses.

In application, periods of extinction are likely not systematically introduced and withdrawn as they were in Experiment 1. For example, during a 10-min period, a parent may implement extinction for screaming, subsequently reinforce screaming, and then implement extinction for another response (e.g., stereotypy), and so on. In other words, laboratory procedures designed to mirror class modification in the natural environment may need to be altered to reflect dynamic (moment-to-moment) changes in contingencies. However, before setting out to study rapidly alternating contingency changes that may better reflect how class modification occurs in the natural environment, methods that permit study of orderly relations in the laboratory should be identified first.

In Experiment 1, experimental control was demonstrated when a reinforcement effect was produced for a single response. For example, when the LE response was placed on extinction and the ME and HE responses were reinforced, a class modification was demonstrated if levels of responding on the ME alternative were elevated, because any responses allocated to the HE alternative would have essentially been wasted (Herrnstein & Loveland, 1975). However, under situations of negative reinforcement, specifically avoidance contingencies, optimal responding can be assessed when multiple responses operate to avoid reinforcer removal. An analogous situation might arise in application as follows. If a token economy is arranged such that three responses (cleaning the chalkboard, delivering books to the library, and turning off computers at the end of the day) function as members of a response class, then the occurrence of cleaning the chalkboard would result in avoidance of one token deduction, and the occurrence of delivering books to the library would result in the avoidance of another token deduction. Similarly, all three responses in the class would result in avoidance of all three token deductions. In other words, more is avoided by the emission of more responses that constitute the class. Experiment 2 was designed to assess the development and modification of a response class in which multiple responses were required to avoid maximal point loss.

EXPERIMENT 2

Development of a Response Class via Physical Effort Manipulations and Negative Reinforcement

Method

Dependent variables and data collection. The same software program used in Experiment 1 was used for Experiment 2. As in Experiment 1, a session consisted of 27 3-min blocks. Experiment 2 focused on two dependent variables. As in Experiment 1, the first was response rate for each alternative (i.e., a click within a specific square). A second dependent variable was the deviation from optimal responding. A changeover penalty, as described in Experiment 1, was also incorporated into Experiment 2. The changeover penalty is particularly important for interpreting the results of Experiment 2. Optimal response rates were calculated based on meeting the response requirement once every 10-s interval. For example, in the LE condition, a participant needed to emit only five responses in a 10-s interval to avoid point loss. Thus, in 1 min, if a participant is engaging in optimal responding, he or she should make 30 responses to the LE square every minute (five responses every 10 s, multiplied by six). It follows that in the LMH condition, if a participant engaged in optimal responding that she would allocate five consecutive responses to the LE square, 15 consecutive responses to the ME square, and 25 consecutive responses to the HE square in every 10-s interval (recall that pilot data indicated that this was possible). Thus, optimal data paths are plotted at 30 responses per minute for the LE square, 90 responses per minute for the ME square, and 150 responses per minute for the HE square. Observed response rates reflect the total responses emitted, which includes responses emitted that did not meet the response requirement. For example, the optimal response rate for the LE option was 30 responses per minute. If a participant emitted 35 responses per minute, it was theoretically possible for him or her to avoid losing nothing. The explanation lies in the changeover penalty. As noted previously, all responses were recorded, but only those that met the consecutive response requirement resulted in avoidance of point loss.

Design and procedure. The order of conditions for a given participant in Experiment 1 remained the same for that participant in Experiment 2; thus, all participants completed Experiment 1 prior to beginning Experiment 2. Experiments 1 and 2 were completed on different days separated by no less than one day (range, 1 to 14, mode = 1). In contrast to Experiment 1, participants did not earn points for meeting ratio requirements in Experiment 2. Instead, they avoided losing points by meeting the ratio requirements. Schedule values were the same as those studied in Experiment 1 (FR 5 LE, FR 15 ME, FR 25 HE), and schedule-correlated stimuli were also the same. Important to note is that the funds provided at the beginning of Experiment 2 were separate from money earned during Experiment 1. In Experiment 2, participants began each session with $20.00 in points and were given 10 s to meet the ratio requirement for a given square that was available to avoid losing points (i.e., each FR schedule was associated with a limited hold). Participants lost \$0.01 for each ratio requirement that was not met. For conditions in which responses to a given square were exposed to extinction, the participant lost \$0.01 every 10 s, and any clicks on that square had no effect on point loss. For instance, when clicks to the ME and HE squares were exposed to extinction, the participant lost \$0.01 from both the ME and HE squares (net loss of \$0.02 every 10 s) and could avoid losing \$0.01 every 10 s only by meeting the ratio requirement for the LE square (i.e., clicking five times). Therefore, if behavior were strictly controlled by the avoidance contingencies (i.e., if the participant behaved optimally), he or she would lose \$0.36 per block or \$1.08 total in that condition (\$0.36 times three blocks). It is possible that the participant could lose more than \$1.08 per condition if he or she did not respond optimally on the LE square (i.e., at least five responses within 10 s). Three blocks of each condition were conducted with each participant. Prior to Experiment 2, participants were read the following:

> The object is for you to avoid losing as much money as you can by clicking the squares on the screen. The money bank you see visible on the screen is separate from your earnings during the first session. Therefore, you are not working to avoid losing money you have already earned. Ready, go.

Participants were not given any additional information concerning the procedures. Questions regarding the procedures were unanswered or the experimenter responded by repeating the previously stated instruction.

A counter was also present during all conditions of Experiment 2. The counter began with a starting balance of \$20.00, and failing to meet the response requirements resulted in deductions from the counter that were visible to participants. During baseline, all three squares were present, but no point loss could be avoided by clicking any of the squares. The participant lost \$0.01 every 10 s from all squares (net loss of \$0.03 every 10 s, net loss of \$0.54 during each block, net loss of \$1.62 during the condition). Following baseline, each participant was exposed to three conditions in which meeting a ratio requirement for only one of the squares resulted in avoiding point loss (response class development, as described in Experiment 1). In each condition of the class-development portion of this study, programmed losses of \$0.01 occurred for the two squares exposed to extinction every 10 s (net loss of \$0.02 every 10 s, net loss of \$0.36 during each block). A total of \$0.18 in losses could be avoided during each 3-min block by meeting the response requirement for the square that was reinforced during each 10-s interval. As in Experiment 1, a brief tone was emitted when the participant met the response requirement on alternatives that were not exposed to extinction. The three conditions that constituted the class-development portion are described next. During the LE reinforcement condition, all three squares were present, but only clicks on the LE square resulted in avoidance of point loss. During the ME reinforcement condition, all three squares were present, but only meeting ratio requirements for the ME square resulted in avoidance of point loss. During the HE reinforcement condition, all three squares were present, but only meeting ratio requirements for the HE square resulted in avoidance of point loss. In the class-demonstration condition, participants could potentially avoid losing all points, because all three squares were available for reinforcement. In this condition, all three squares were present, and avoidance of point loss was permitted for each square in accordance with the ratio requirements of each square (i.e., five responses for LE, 15 responses for ME, and 25 responses for HE). No programmed losses were scheduled because all point loss could theoretically be avoided. Following the class-demonstration condition, the class-modification conditions followed during which only two of three options produced avoidance of point losses. During all three of the class-modification conditions, programmed losses of $0.01 occurred every 10 s for the square exposed to extinction (net loss of $0.01 every 10 s, net loss of $0.18 during each block). A total of $0.36 in losses could have been avoided during each block by meeting the response requirements for both of the squares that were reinforced during each 10-s interval. In the MH condition, all three squares were present, but only clicks on the ME and HE squares resulted in avoidance of point loss. Unlike the positive reinforcement contingencies assessed in Experiment 1, response allocation to both ME and HE squares was optimal. In the LH condition, all three squares were present, but only clicks on the LE and HE squares resulted in avoidance of point loss. Response allocation to both LE and HE squares was optimal. As in Experiment 1, the MH condition was replicated for all participants in Experiment 2. Finally, during the LM condition all three squares were present, but only clicks on the LE and ME squares resulted in avoidance of point loss. Response allocation to both LE and ME squares was optimal.

Results and Discussion

Figures 5 through 8 depict response rates on each alternative as well as the optimal response rate for all participants. As in Experiment 1, results are summarized globally, and nuances are noted. The following results are summarized in terms of mean responding observed in each condition. Compared to some of the reinforcement phases that followed, participants engaged in low response rates during baseline. During the LE condition, responding was highest on the LE square and low on the ME and HE squares for 11 of 11 participants. Although Pepromene emitted the most responses on the LE square, responses were below optimal rates. During the ME condition, responding was highest on the ME square and low on the LE and HE squares for 11 of 11 participants. Although Pepromene emitted the most responses on the ME square, responses were below

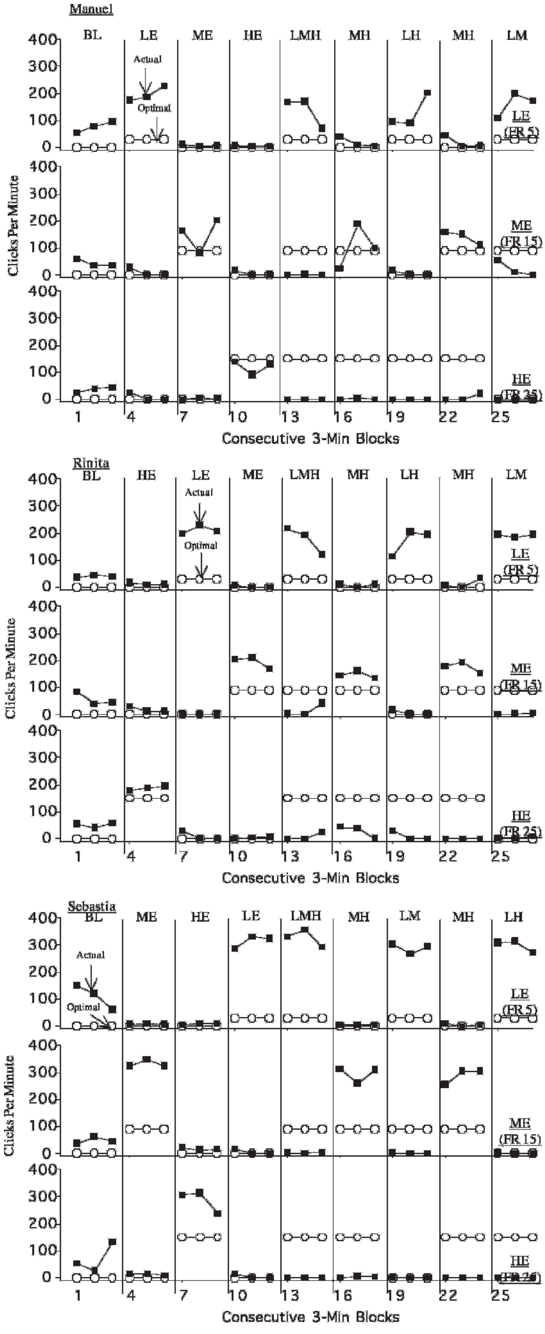

Figure 5. Results of Experiment 2 for Manuel, Rinita, and Sebastian. Data depict observed (filled circles) and optimal responses (open circles) per minute across the LE (top), ME (middle), and HE (bottom) options for each participant. LE condition: FR 5 LE, EXT ME and HE; ME condition: EXT LE, FR 15 ME, EXT HE; HE condition: EXT LE and ME, FR 25 HE; LMH condition: FR 5 LE, FR 15 ME, FR 25 HE; MH condition: EXT LE, FR 15 ME, FR 25 HE; LH condition: FR 5 LE, EXT ME, FR 25 HE; LM condition: FR 5 LE, FR 15 ME, EXT HE.

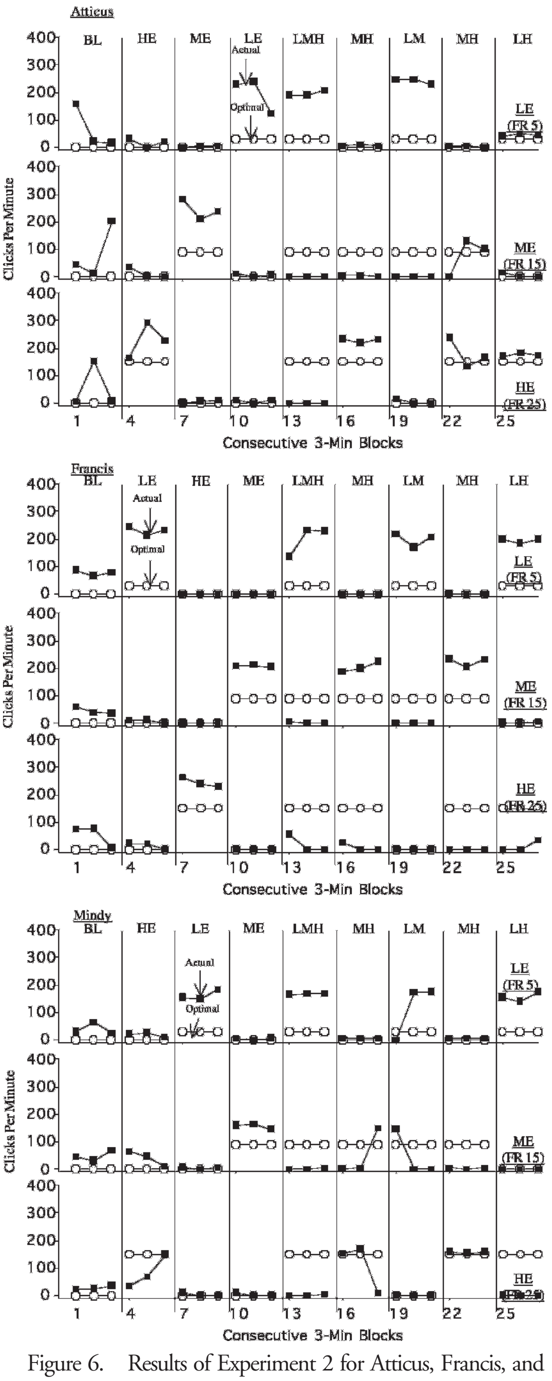

Figure 6. Results of Experiment 2 for Atticus, Francis, and Mindy. Data depict observed (filled circles) and optimal responses (open circles) per minute across the LE (top), ME (middle panel), and HE (bottom) options for each participant. LE condition: FR 5 LE, EXT ME and HE; ME condition: EXT LE, FR 15 ME, EXT HE; HE condition: EXT LE and ME, FR 25 HE; LMH condition: FR 5 LE, FR 15 ME, FR 25 HE; MH condition: EXT LE, FR 15 ME, FR 25 HE; LH condition: FR 5 LE, EXT ME, FR 25 HE; LM condition: FR 5 LE, FR 15 ME, EXT HE.

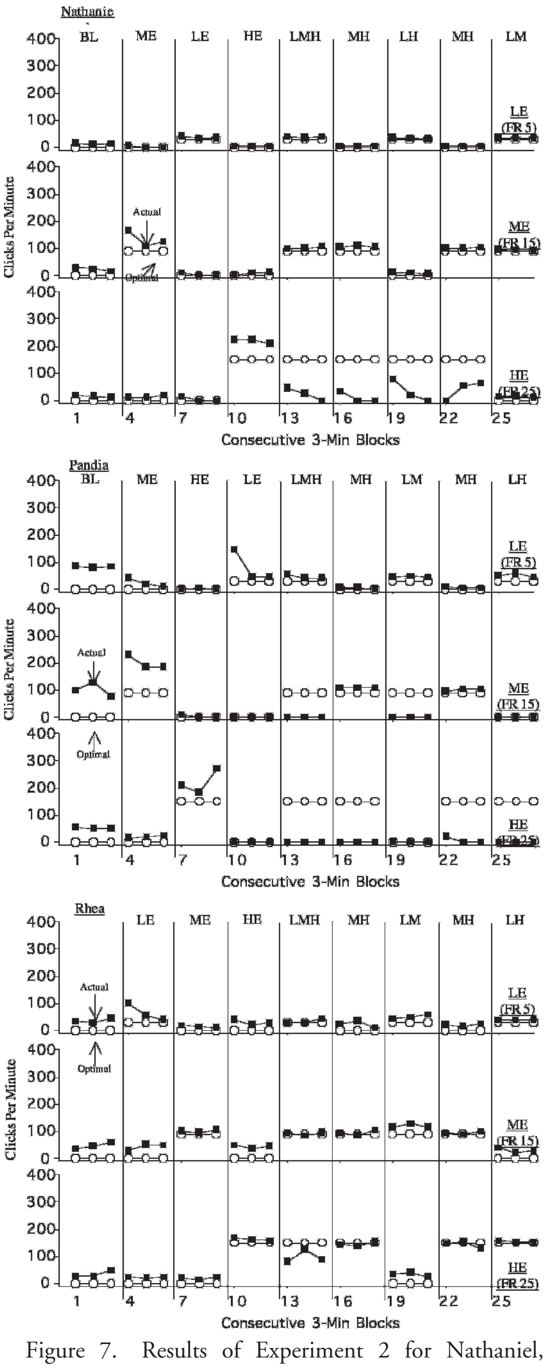

Figure 7. Results of Experiment 2 for Nathaniel, Pandia, and Rhea. Data depict observed (filled circles) and optimal responses (open circles) per minute across the LE (top), ME (middle), and HE (bottom) options for each participant. Condition descriptions are the same as those described for Figure 6.

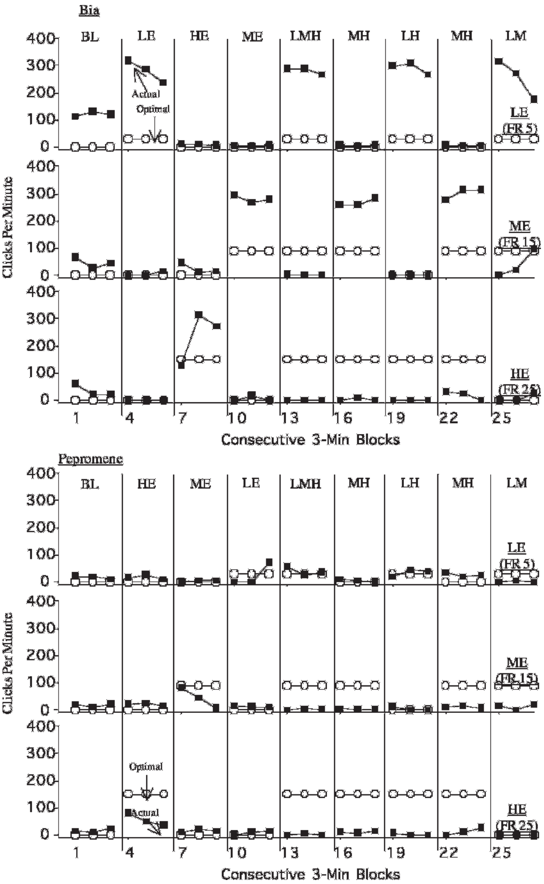

Figure 8. Results of Experiment 2 for Bia and Pepromene. Data depict observed (filled circles) and optimal responses (open circles) per minute across the LE (top), ME (middle), and HE (bottom) options for each participant. LE condition: FR 5 LE, EXT ME and HE; ME condition: EXT LE, FR 15 ME, EXT HE; HE condition: EXT LE and ME, FR 25 HE; LMH condition: FR 5 LE, FR 15 ME, FR 25 HE; MH condition: EXT LE, FR 15 ME, FR 25 HE; LH condition: FR 5 LE, EXT ME, FR 25 HE; LM condition: FR 5 LE, FR 15 ME, EXT HE.

optimal rates. During the HE condition, responding was highest on the HE square and low on the LE and ME squares for 11 of 11 participants. Although Mindy and Pepromene emitted the most responses to the HE square, responses were well below optimal rates. Both Mindy and Pepromene experienced the HE condition immediately following baseline.

During the class-demonstration condition, response rates were high on the LE square and low on the ME and HE squares. Responses were typically allocated to only the LE square, although allocating responses to each square would have been optimal to avoid point loss. For two participants, although response rates were high to the LE square, responding was highest on the ME square for Nathaniel and on the ME and HE squares for Rhea. Because these participants engaged in optimal responding in that responses were allocated to more than one alternative, meeting the ratio requirements for the other options necessitated more frequent responding. That is, if meeting requirements for both the LE and HE square, responses to the HE square would necessarily be higher because it required 25 responses and the LE square required five responses.

During the class-modification conditions that followed, responding was typically highest to the lowest effort schedule not exposed to extinction. However, responding on more than one alternative was not observed for the majority of participants. During both MH conditions, responding was high on the ME square and low on the LE and HE squares during at least one or both of the MH conditions for 9 of 11 participants (Mindy and Pepromene were the exceptions). During the first MH condition, Atticus allocated the highest response rates to the HE square and lower response rates to the LE and ME squares. However, during the second MH condition, Atticus responded nearly optimally, in that responses were allocated to the ME and HE squares. Mindy initially emitted the highest response rates on the HE square during the first MH condition; however, responses to the ME square increased and responses to the HE square decreased during the last block of this condition. During the second MH condition, nearly all of Mindy's responses were allocated to the HE square, which indicates not only nonoptimal responding (as near-zero responses were allocated to the ME square) but inefficient responding. Responding for Pepromene was low on all three squares during both MH conditions. Rhea behaved optimally during both of the MH conditions, in that responses were allocated to both the ME and HE squares. During the LH condition, responding was high on the LE square and low on the ME and HE squares for 11 of 11 participants. Atticus and Rhea behaved optimally by responding on the LE and HE squares. During the LM condition, responding was high on the LE square and low on the ME and HE squares for 10 of 11 participants. Pepromene was the exception. Mindy initially allocated nearly all responses to the ME square during the first 3-min block, but responses to the LE increased and responses to the ME decreased in subsequent blocks. Nathaniel and Rhea responded optimally during this condition by responding on both the LE and ME squares. Bia also responded on both the LE and ME options, but did so only in the last block of this condition.

Results of Experiment 2 indicate that a response class was successfully developed via negative reinforcement (avoidance) contingencies for all 11 participants and was successfully modified for 10 of the 11 participants. Pepromene was the exception. These results suggest that response classes could be developed in the human operant laboratory using negative reinforcement procedures, and that the inclusion of multiple responses did not result in optimal responding for the majority of participants. Atticus, Nathaniel, and Rhea exhibited optimal responding during most blocks of one or more conditions in Experiment 2. The term *optimal* means that participants emitted responses on two or more alternatives when the avoidance contingencies promoted doing so. Strictly speaking however, responding 40 times per minute when the contingency calls for only 30 responses is not optimal. In other words, when participants did emit more responses than were required by the contingencies, the difference was functionally indiscriminable. Avoidance is a particularly complex phenomenon that has been shown to be insensitive to changes in the frequency of the removal of reinforcing stimuli (Cherek et al., 1990). As it relates to matters of direct applied significance, this is encouraging.

During the class-demonstration conditions, performance was highly similar to that observed during Experiment 1. Participants reliably selected the least effortful option. During the class-demonstration condition of Experiment 2, participants also selected the least effortful response option but avoided roughly one third of deductions by doing so. If each of the three responses in the current study is conceptualized as a form of problem behavior, each associated with progressively more effort, results of Experiment 2 suggest that only the less effortful response will persist. In which case, extinction would need to be arranged for only one response (e.g., the most severe form of problem behavior) because given the two remaining options, emission of the lower effort response was most probable for the majority of participants in Experiment 2.

For extinction of the higher effort responses to occur, contingencies may need to be arranged so that all other responses are systematically exposed to extinction. For instance, assume a child emits three responses that vary in degrees of effort from screaming, aggression, and SIB. For extinction of aggression (ME) to occur, screaming (LE) would need to be exposed to extinction to evoke aggression. Therefore, for extinction of SIB (HE) to occur, screaming and aggression would need to be exposed to extinction. This arrangement was not assessed in the current study, but future research may assess such an arrangement to further inform clinical applications of extinction to response classes.

Because all participants experienced Experiment 1 (in which emission of one response, the least effortful, was optimal) prior to Experiment 2 (in which multiple responses were sometimes required to avoid all possible deductions), the persistent responding on only a single alternative may be explained by the proximate history. Current research in our laboratory has been designed to assess performance when individuals experience the negative reinforcement condition prior to the positive reinforcement condition. This research may yield insight into what effect, if any, experimental history may have on behavior assessed under both positive and negative reinforcement contingencies.

Although the changeover penalty was a necessary procedural component because we used FR schedules, such penalties may not be analogous to clinical scenarios. Future research may be designed to model intervention strategies that are used commonly in application. It should also be noted, however, that in application, extinction alone would likely not be the intervention of choice. In combination with communication training (e.g., Carr & Durand, 1985), an appropriate and functional alternative response might offset some of the negative side effects associated with extinction. The present study, however, was a preliminary investigation designed to determine the feasibility of the human operant laboratory to study response class development and modification. Thus, to inform matters of application, laboratory analogues of class development and modification could be designed to include common behavioral treatments designed to eliminate problem behavior.

Given the exploratory nature of the present research, conclusions must be drawn cautiously. First, the fact that this experiment was conducted in slightly more than 80 min was cited as a strength, but may also explain why participants were largely insensitive to situations in which responses on multiple alternatives was optimal. The fact that most participants selected one and only one response option suggests that more time may be required to establish avoidance that involves multiple responses in a class. For example, in the nonhuman animal laboratory, histories involving between 212 and 726 hr of training have been reported prior to extinction conditions (e.g., Galizio, 1999). Second, the extended histories that individuals with intellectual disabilities bring to bear on experimental manipulations would certainly influence performance. Future research may be designed to investigate a longer experimental history by way of replicating more of the experimental conditions for each participant. That is, a third potential limitation of this research is that only one of the nine conditions was replicated. More replications within participants may result in greater sensitivity to the experimental contingencies. A fourth limitation of the study, which also concerns the duration of the experiment, is that new contingencies were not introduced depending on the participants' behavior; rather, all participants experienced the same duration of each condition.

Fifth, although the relatively short duration of each experiment may have contributed to the insensitivity to the experimental contingencies, fatigue may have also contributed to observed performance. That is, for each experiment, a participant was required to remain seated at a computer for approximately 80 min, and the frequency of responses required over this period of time may have fatigued the participant and suppressed responding.

GENERAL DISCUSSION

Results of Experiment 1 were consistent with those reported by Shabani et al. (2009). In this respect, the utility of translational research to understand problems of clinical importance was demonstrated. Experiment 2 involved the construction of an analogue response class produced via avoidance. Although avoidance is presumably responsible for a wide range of socially relevant behavior (e.g., taking prenatal vitamins or smoking cessation during pregnancy), it has been understudied. Results of Experiment 2 place the study of avoidance in a clinically meaningful context to understand the development and modification of response classes.

The finding that the majority of participants failed to avoid all possible point losses can be attributed to several possible reasons. For example, reinforcer delay may have played a role. Although the computer emitted a tone when a response requirement was met, the counter was updated at the end of the 10-s interval. These stimuli may have been too delayed to exert control over the participants' behavior. Another possible explanation is that the effort required to avoid all possible point deductions was too great to strengthen such responding, and this may have also been the case in Experiment 1. In other words, the avoidance of point deductions was reinforcing for only the relatively lower effort response but not for other response alternatives. Future research might examine the extent to which response classes developed in the laboratory can be modified by manipulating magnitude of reinforcement, which is likely a contributing factor to response classes made up of problem behavior that have been described in the literature. In applied contexts, SIB might result in differentially larger magnitudes of reinforcement when compared to screaming or vice versa. Future laboratory research might be designed to model the combined effects of effort and magnitude manipulations of the development and modification of response classes under both positive and negative reinforcement contingencies.

The effect of an establishing operation represents yet another possible explanation for the finding that the majority of participants did not avoid all possible point deductions in Experiment 2. That is, the acquisition of optimal performance might have been retarded because money earned during Experiment 1 altered the reinforcing efficacy of money available to retain during Experiment 2. This suggests at least two areas for future research. First, one manipulation might involve having participants work to avoid point-loss deductions in Experiment 2, using the funds earned by each participant in Experiment 1. Second, budget manipulations might improve the differential sensitivity of point-loss avoidance. Had participants in the present investigation been given smaller amounts of money such that the starting balance could be exhausted by session's end, then the value of avoiding point losses might have been enhanced. In the context of a classroom token economy, this might involve arranging beginning token balances of 100 (maximum possible), 50, or 25 at the beginning of the week, with avoidance of point losses arranged for a class of classroom responsibilities throughout the week.

Other translational research studies may seek to examine response classes in clinical settings to enhance treatment decisions. Because the study of response classes developed via physical effort in applied settings can be subjective, the human operant setting is a promising outlet to study these and other applied phenomena. For example, determining the physical effort required to lift a 2-kg weight versus a 10-kg weight can be quantified, whereas the effort associated with screaming versus self-injury cannot (at least not easily). In addition, because we cannot systematically investigate how response classes that involve forms of severe problem behavior originate, the study of potentially analogous procedures in the human operant laboratory provides a convenient and well-controlled environment in which to model environmental contingencies that may be operating in the natural environment. Human operant research designed to address matters of applied significance may be extended to several areas (e.g., treatment integrity, time-based stimulus presentation, differential reinforcement of other behavior); however, here we highlight resurgence and punishment.

Resurgence

Response resurgence refers to the return of previously extinguished behavior during the extinction of more recently reinforced behavior

(Lieving, Hagopian, Long, & O'Connor, 2004). Resurgence is of considerable relevance to the study of problem behavior and was assessed recently by Volkert, Lerman, Call, and Trosclair-Lasserre (2009). Volkert et al. showed that problem behavior could be eliminated when an alternative response produced the functional reinforcer, and that problem behavior recovered when both it and the alternative response were exposed to extinction. Volkert et al. went on to assess the recovery of problem behavior under lean reinforcement schedules for the alternative response (not extinction per se) and found that problem behavior also recovered under these conditions. Because the human operant laboratory can incorporate noninjurious responses as the target, the procedure described in the present study could be applied to assess the parametric effects of schedule thinning for appropriate behavior. For example, Volkert et al. tested for resurgence by increasing an FR response requirement for appropriate behavior from 1 to 12. The range of values assessed could be tested more thoroughly in the human operant laboratory to allow a parametric analysis of the conditions that contribute to resurgence without the risk of harm that is associated with research on problem behavior. Informed by findings from the human operant laboratory, researchers might then extend these findings and procedural manipulations to the emission of problem behavior.

Punishment

Lerman and Vorndran (2002) pointed out that research on punishment has been on a decline. The controversies that surround punishment exist because of some misunderstandings about aversive control in general and punishment in particular, and because the presumed side effects of aversive control are greater than those of positive reinforcement (Perone, 2003). As these and other authors (e.g., Vollmer, 2002) have noted, however, punishment is effective, may sometimes be necessary, and should be the subject of further behavior-analytic research. As Vollmer characterized the matter, "punishment happens." The current model seems ideal for further investigation of punishment and some of the factors that contribute to its effectiveness. The procedures used in the present study could be used to assess conditions of intermittent punishment and intermittent reinforcement, which are very likely at work in the natural environment. Laboratory studies could be designed to identify the integrity with which punishment contingencies must be applied to ensure response suppression. Similarly, some responses may be relatively less severe (e.g., obscenities in the classroom) whereas others might be more egregious (e.g., physically assaulting a classmate). The study of differential punishment contingencies (e.g., greater token deductions or increased exposure to benign noxious stimulation) may be effectively carried out in the human operant laboratory, and these represent only a few suggestions for the study of punishment as a therapeutic operation.

In the present set of experiments we attempted to model one aspect that might contribute to response classes (response effort) along two dimensions (positive and negative reinforcement). We do not suggest that effort, for example, is the only contributor to response classes worthy of study. Rather, we suggest that it is one, and one that can be effectively modeled in the human operant laboratory. Results from this study may inform future research as well as treatment decisions in applied settings. Such experimental procedures are currently in preparation to further inform the study of behavior with clinically relevant populations. Additional research designed to study the development and modification of response classes is warranted and might be carried out most successfully given coordinated efforts by basic, applied, and translational researchers.

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